

NASA GRC Academy 2010



MASE

Modular & Adaptive Space Environments

A Universal Infrastructure

Howard Liles, Ryan Miller, Kylee Underwood, Robyn Bradford, Adam Harden,
Chelsey Erickson, Nathan McKay, Shanita Wilburn



NASA Academy - Who We Are



Shanita Wilburn
Tuskegee University

Chelsey Erickson
University of Wisconsin

Adam Harden
MSOE

Robyn Bradford
Central State University

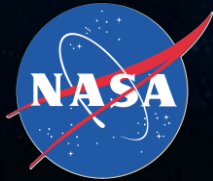
Nathan McKay
University of Michigan

Ryan Miller
Purdue University

Howard Liles
M.I.T.

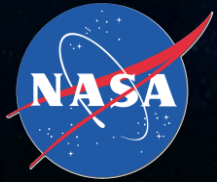
Kylee Underwood
West Virginia University

Ron Turba
Vanderbilt University



Outline

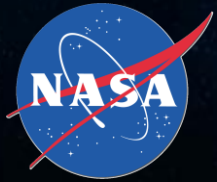
- Introduction
- Goals
- Habitable Places
- Modular Design
- System specifics
 - Exercise
 - Filtration Systems
 - Sleeping and Habitation
 - Power Systems
 - Environmental Hazards
 - Thermal Management
 - Radiation Shielding
 - Communications
 - Travel Times and Storage
 - ISRU
 - Transportation
 - Waste Management
 - Water Production
 - Oxygen Production
- Outreach
- Conclusion



Introduction

- **Design a reliable & adaptable habitat**
 - Benefits from modular design
 - Facilitates cost savings
 - Speeds up future space explorations
 - Applies directly to Earth scenarios

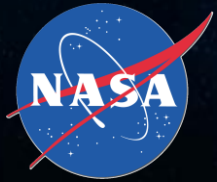




Goals

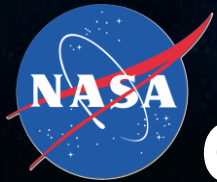


- Support NASA Mission of expanding the space frontier.
- Design a modular and adaptive living habitation to speed the colonization of other planets.
- Extend mission to terrestrial applications.
- Stimulate interest in NASA among youth, specifically in the local community.



Habitability

- Habitable: a place capable of sustaining human life
 - Breathable atmosphere
 - Drinkable water
 - Temperate climate
 - Edible Food
- Modifications often necessary to create habitable places
- Project “modifies” environment by many needed provisions with while making use of ISRU techniques



Ganymede



- Similar to Earth
- Subsurface Oceans

Callisto



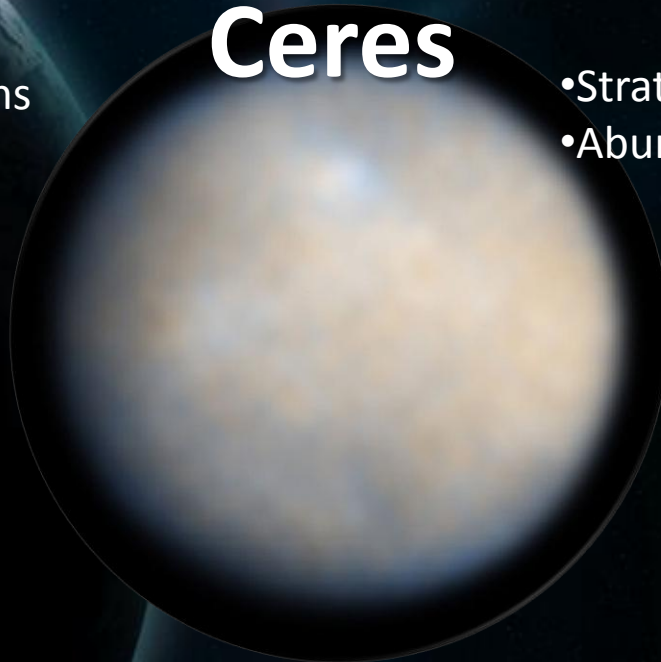
- Subsurface Oceans
- Low radiation

Europa



- Subsurface Oceans
- Potential for life

Ceres



- Strategic Location
- Abundance of water





Mars

- Similar to Earth
- Presence of water



Titan

- Dense Atmosphere
- Earth like weather

Phobos

- Easy launch to Mars
- Possible water ice

Moon

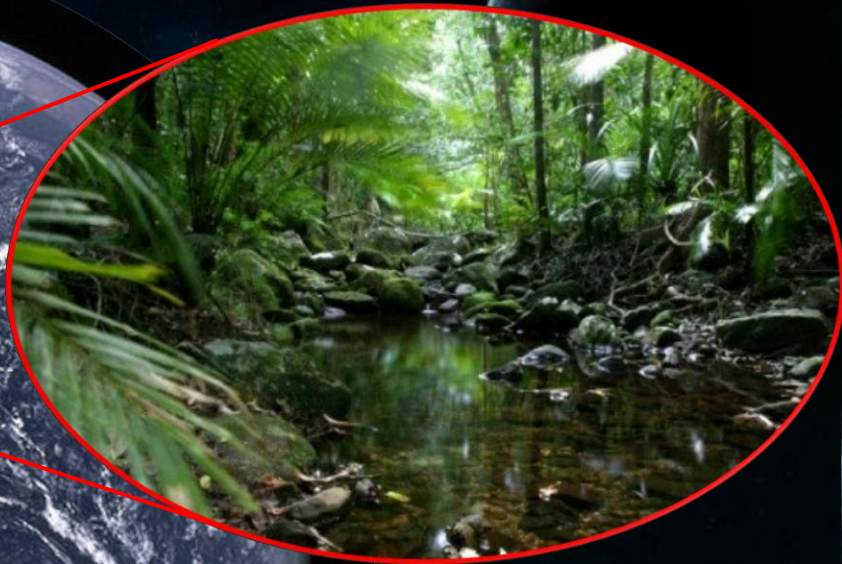
- Strategic Location
- Past Lunar Experience

Earth



Desert

- Harsh environment
- Minerals



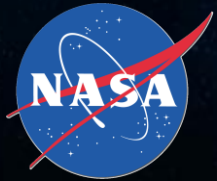
Rainforest

- Ideal environment



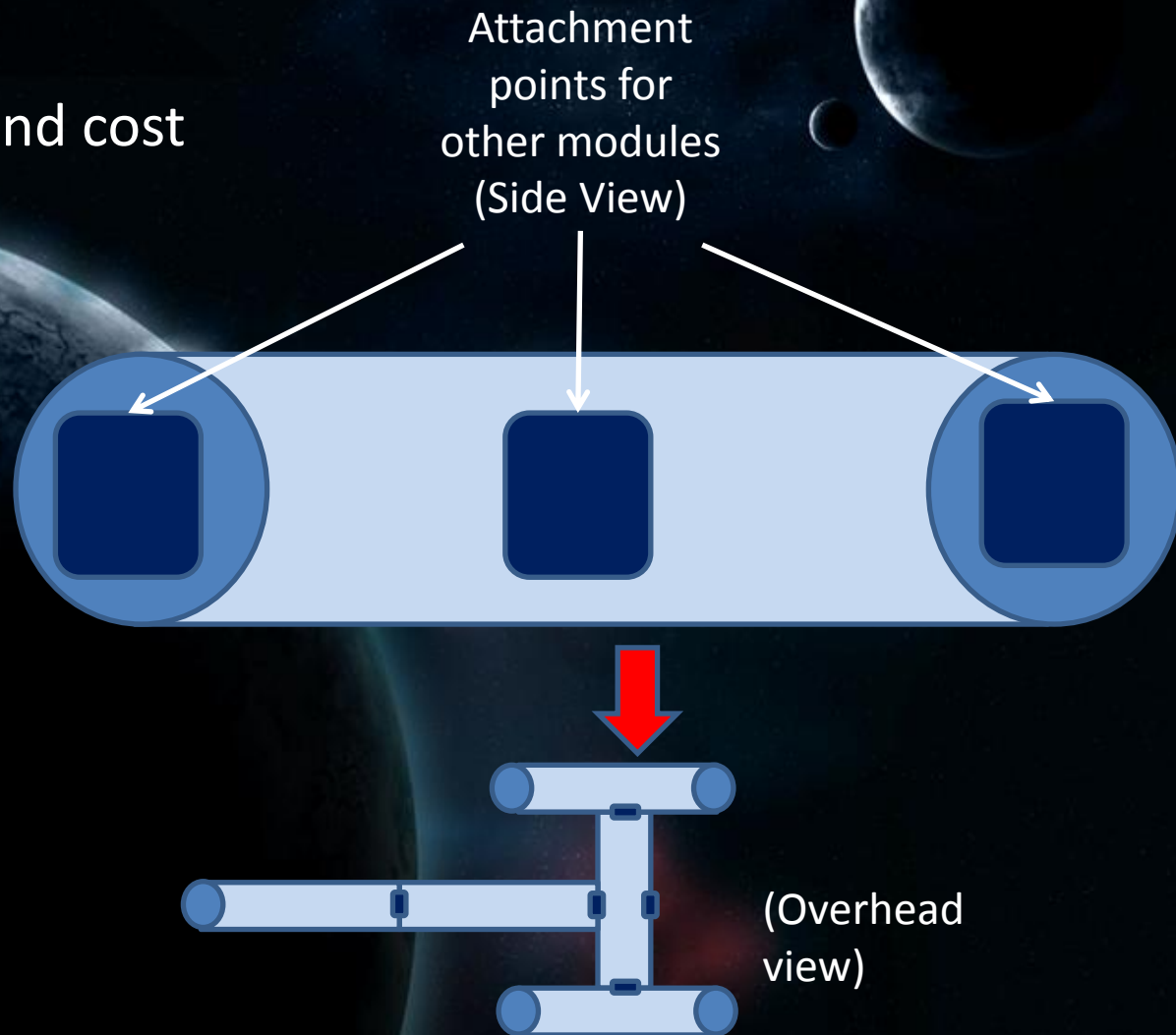
Desert

- Harsh environment
- Climate Study



Modular Design

- Functional Systems
- Repeatable Modules
- Reduced complexity and cost
- Adaptability





Exercise



To grow, repair, and maintain healthy bones, muscles, and ligaments, regular exercise is critical.

Three typical Exercise Machines

- ☾★ Treadmill - aerobic machine that also stimulates bone and ligament health through ground reaction forces
- ☾★ Stationary bicycle – aerobic machine and acts as a resistance machine for muscle maintenance
- ☾★ Weight machine – supports muscle health in upper and lower limbs and in the core

Three Systems

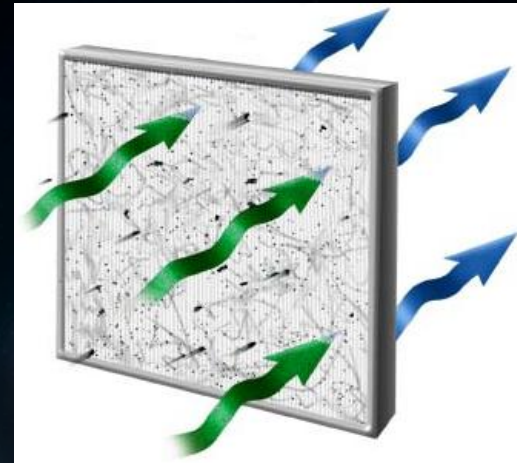
- ☾★ Earth locations - use machines as they would typically be used on Earth
- ☾★ Mars, Moon, Ganymede – increased resistance on bicycle and weight machine; bungee tether on treadmill
- ☾★ Titan, Europa, Callisto, Ceres, Phobos – tethered to treadmill; increased bicycle resistance; resistance bands; possibly other stimulation

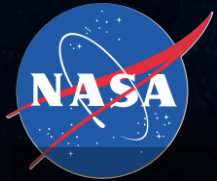


Filtration Systems

Each module will have a filtration system to remove internally generated dust and intrusion dust.

- ☾★ High Efficiency Air Particulate (HEPA) filters
- ☾★ Rolling-Media Filters
- ☾★ Reverse Flow Cyclones
- ☾★ Pre-filter Screens
- ☾★ Electrospray Filters
- ☾★ Filters to remove water from air and bring it to water purification system. (Callisto, Titan, Ganymede, Earth Antarctic)





Sleeping and Habitation



There are two basic types of sleeping styles considered for the living quarters module.

Traditional Method
using cots, bunk beds,
or hammocks



(Earth, Moon, Mars,
Ganymede)

Horizontal beds with
straps for sleeping
restraint



(Titan, Europa, Callisto,
Ceres, Phobos)



Power System



Titan, Europa, Ganymede, Callisto, Ceres, Moon, Mars, Phobos

- **Fission Surface Power**
 - Solar power not practical
 - Modular system
 - Adaptable to all space environments

Earth Environments

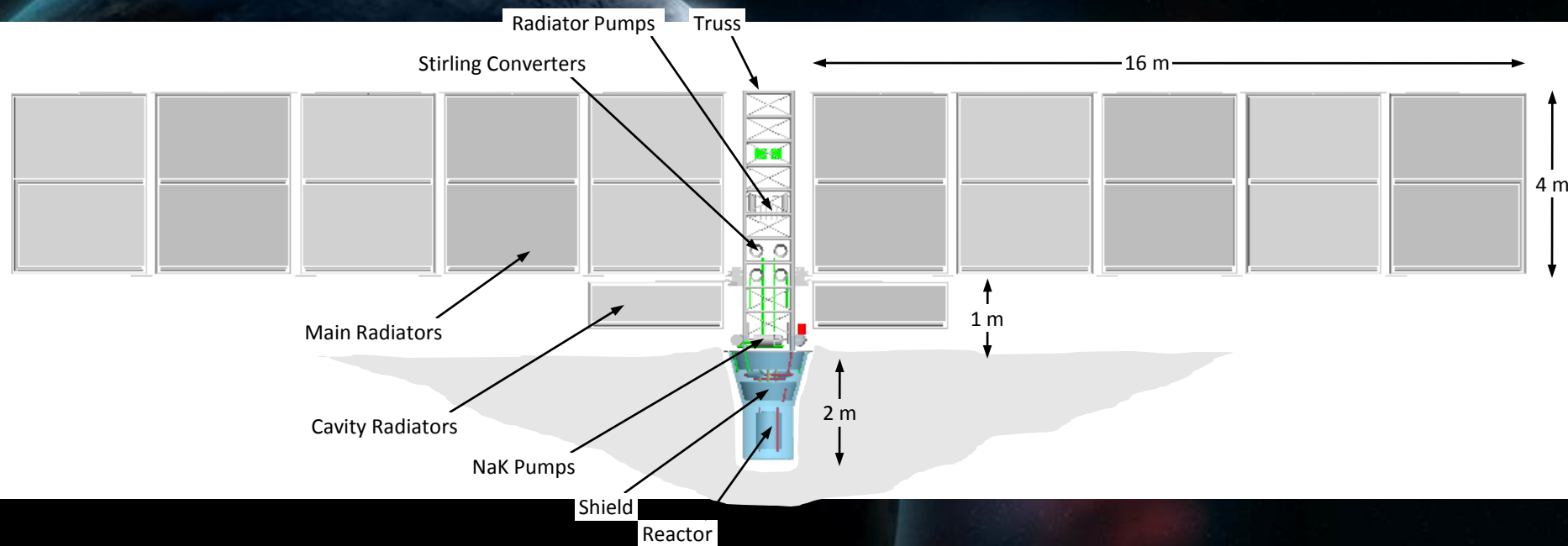
- Rainforest: Solar panels in clearing, fossil fuel generators
- Desert: Solar panels, fossil fuel generators
- Antarctica: Wind power, solar, fossil fuel generators



Fission Surface Power Reference Concept

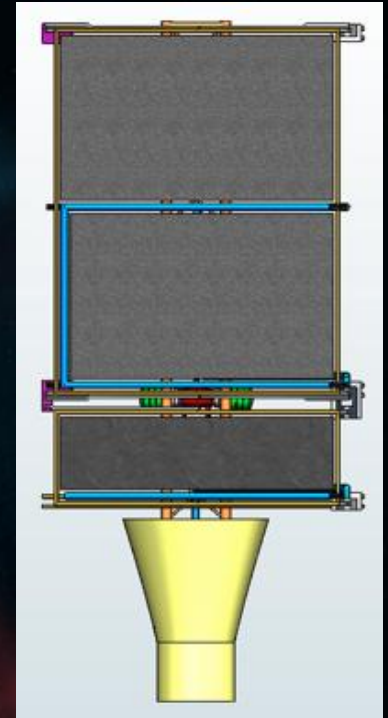
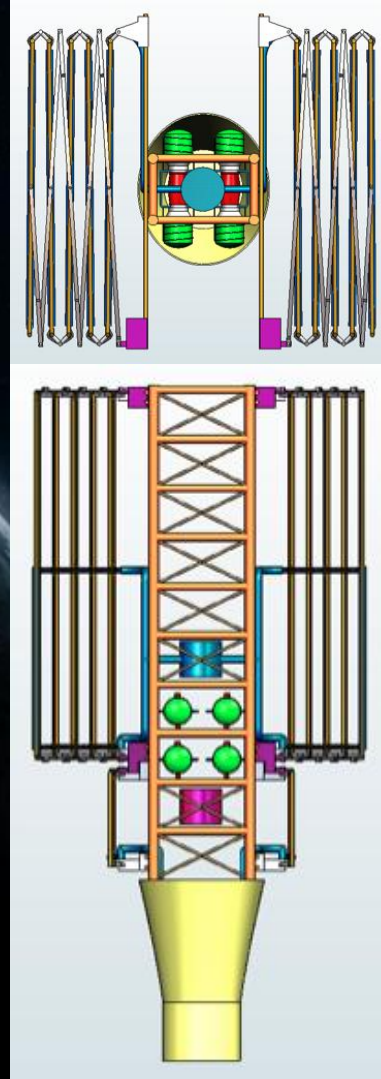
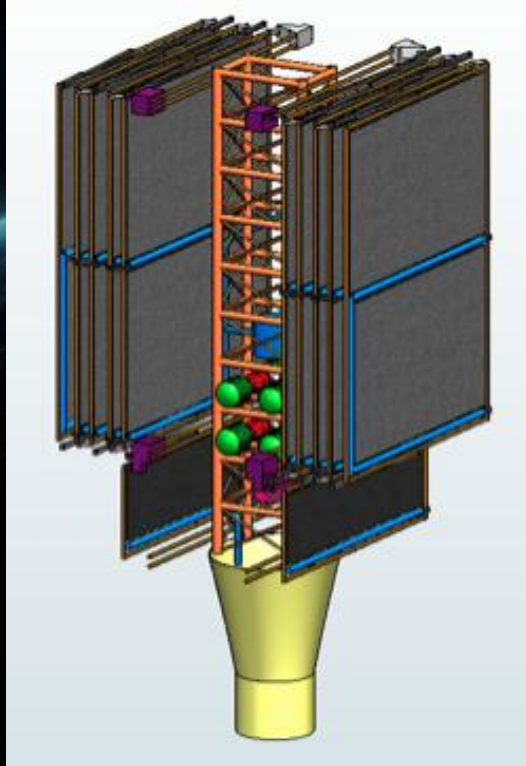


- Modular 40 kWe system with 8-year design life
- Designed initially for Moon/Mars - adaptable to other environments
- Emplaced configuration with regolith shielding augmentation permits near-outpost sitting (<5 rem/yr at 100 m Separation)
- Estimated to weigh 5820 kg



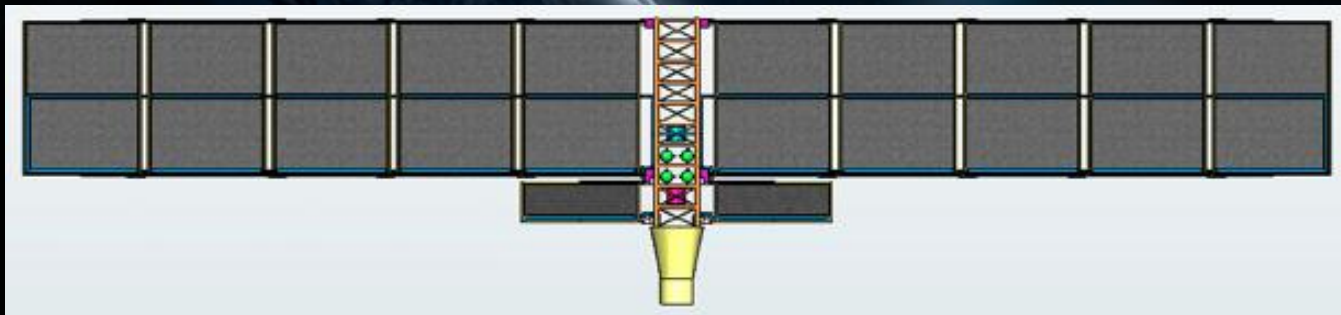
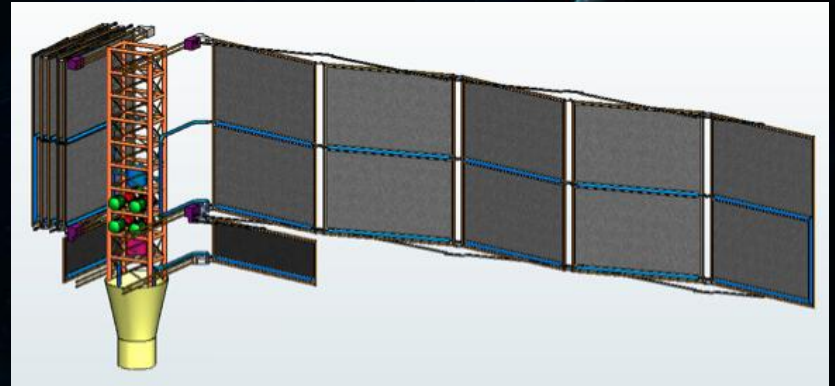
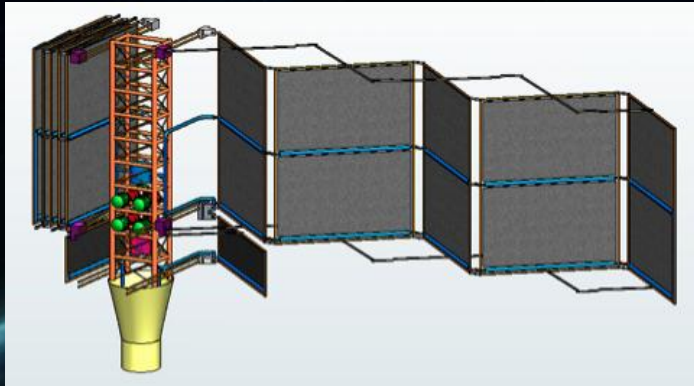


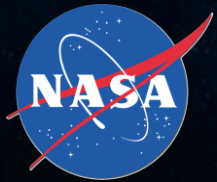
Reference Concept - Stowed





Reference Concept - Deployed

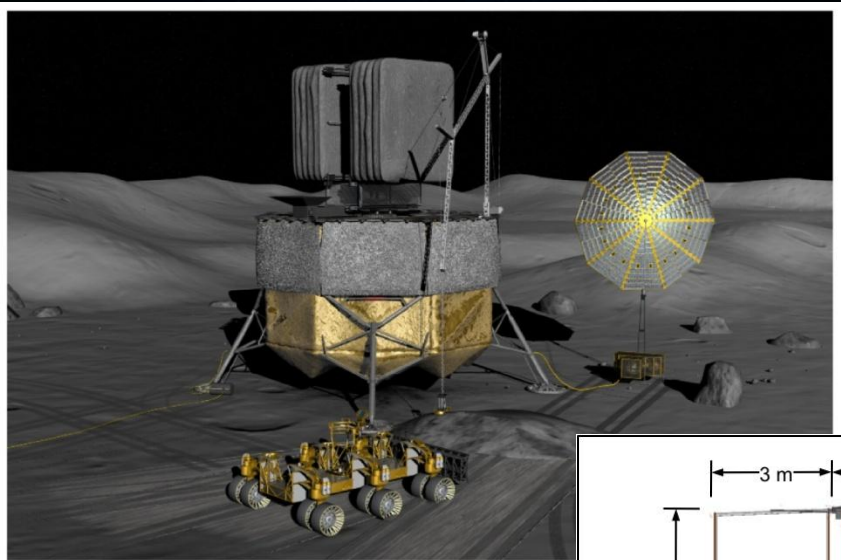




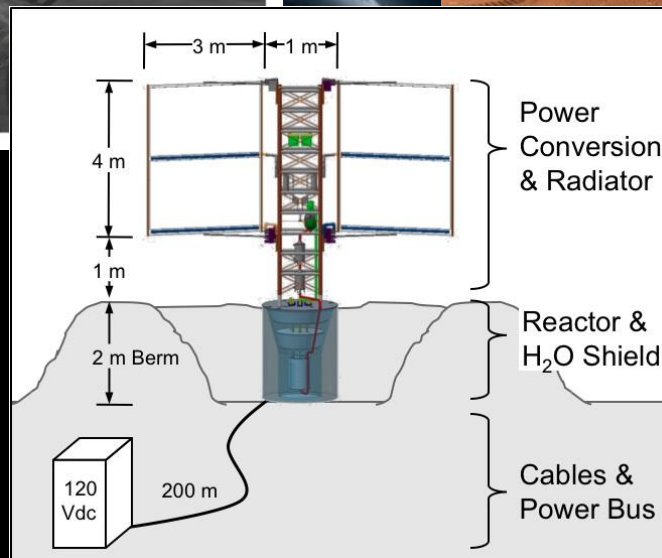
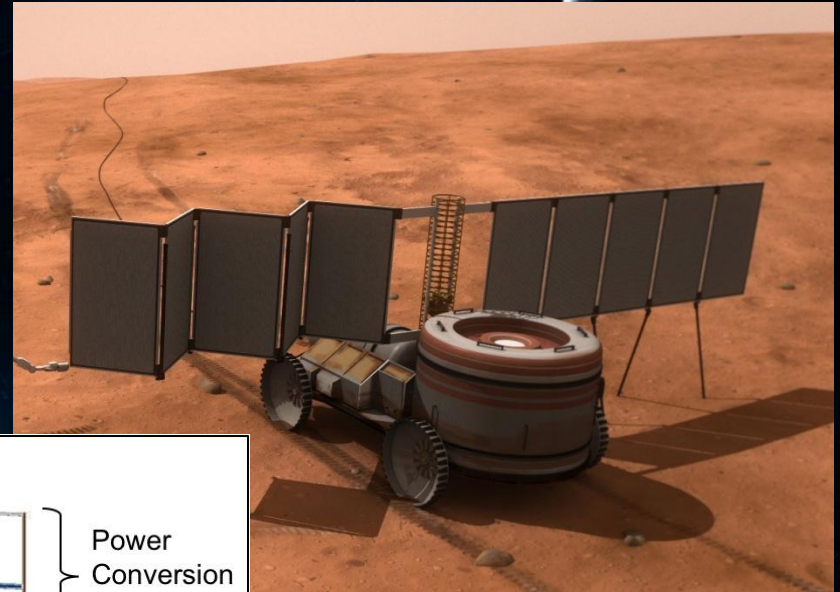
FSP Variants



Lander Integrated



Cart Deployed



Movable



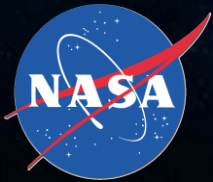
Environmental Hazards

Hazard	Environment Present	Avoidance Measures
Cryovolcanoes	Titan	Proper heat shielding, attach to ground
High Winds	Titan, Earth Antarctic	Avoid sail-like structures, attach to ground
Seismic Activity	Titan, Ganymede, Europa	
Micrometeoroids	Ganymede, Europa, Callisto, Ceres, Moon, Phobos	Proper shielding (Stuffed Whipple Shield)
Dust Storms	Mars, Earth Desert	Protect and clean sensitive equipment

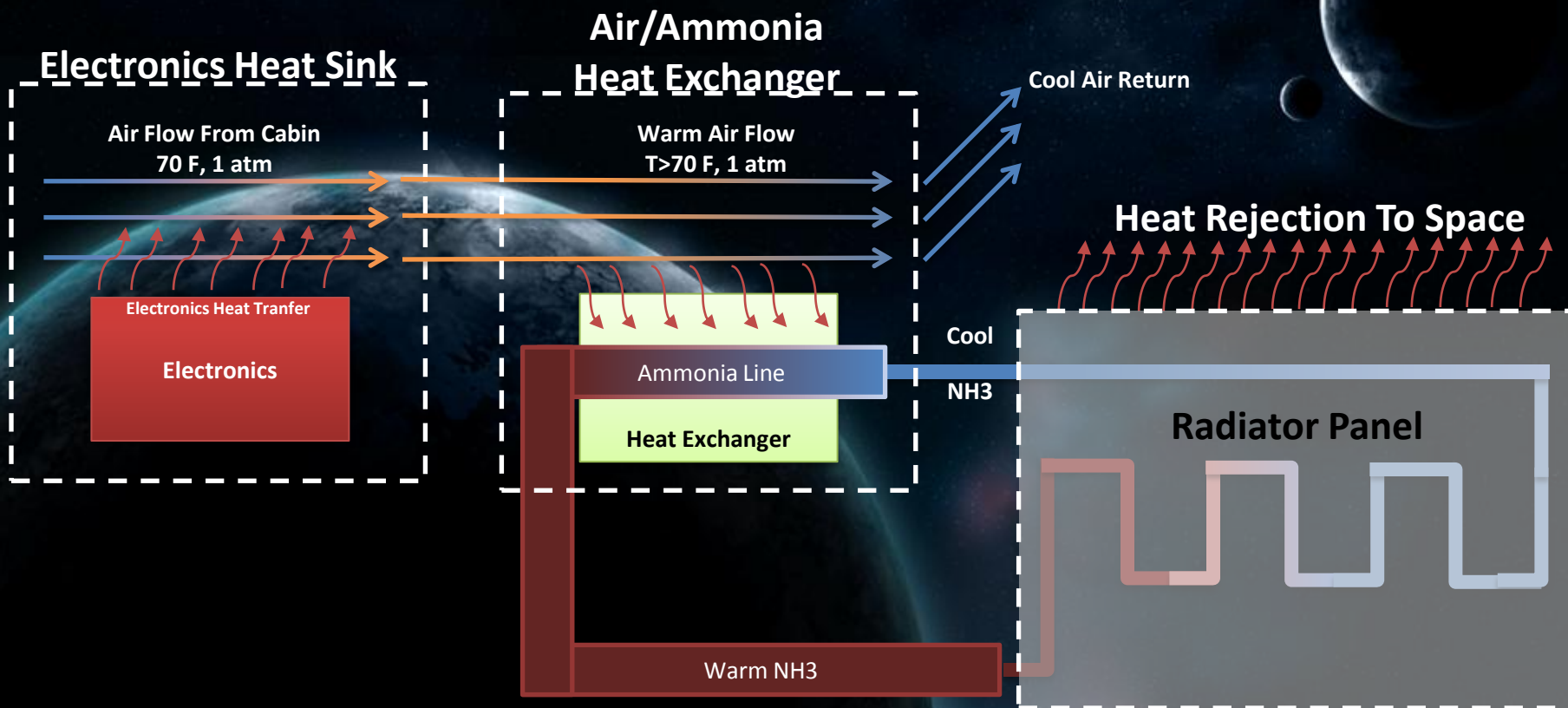


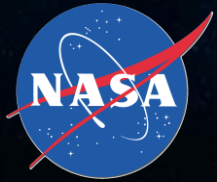
Thermal Management

- Responsible for keeping equipment within temperature limits
- Consists of two systems:
 - Thermal Insulation
 - Waste Heat Rejection
- Different Configurations for Different Environments
 - Multi-Layer Insulation (MLI) used in vacuum
 - Very low conductance material used in atmospheres
 - Various waste heat rejection methods available



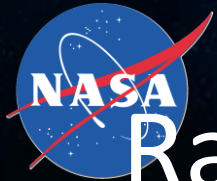
Thermal Management





Thermal Management

- Goal: Size Air/Ammonia heat exchanger
- Steady flow energy equation determines air temperature increase over electronics
- Air/Ammonia heat exchanger analyzed via Effectiveness-NTU method
- Radiator analyzed with Stefan-Boltzmann equation
- Solution iterated upon to reconcile inlet/outlet ammonia temperatures of heat exchanger/radiator



Radiation Concerns in Deep Space



- Two Sources of Radiation: Galactic Cosmic Rays (GCR's) and Solar Particle Events (SPE's)
- Galactic Cosmic Rays mainly consist of high charge and high energy particles that penetrate the solar system from interstellar space
 - Primary concern for long term missions
 - Most difficult to shield against
 - Radiation levels/particle fluence oscillates over the sun's solar cycle
- Solar Particle Events consist of unusually large particle discharges from the sun.
 - Usually occur during periods of peak solar activity
 - Relatively rare events
 - Consist mostly of protons
 - Easier to shield against, but can provide massive doses of radiation in a relatively short period of time if not properly shielded against.



Radiation Health Effects

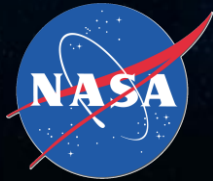
- Little is known about the health effects of GCR's and SPE's
- Currently using LEO radiation exposure limits
- Unit of radiation exposure is the Sievert, which applies biological waiting factors to the type of radiation absorbed by the body.

Exposure Interval	BFO Dose Equivalent (cSv)	Ocular Lens Dose Equivalent (cSv)	Skin Dose Equivalent (cSv)
30-day	25	100	150
Annual	50	200	300
Career	See Table 2	400	600

Figure R-1: Recommended dose equivalents for organs of all ages. BFO = Blood Forming organs. Recommended by NCRP-132 (2001). taken from reference [a]

Age	25	35	45	55
Male	0.7	1.0	1.5	2.9
Female	0.4	0.6	0.9	1.6

Figure R-2: Recommend whole body exposure limits for equivalent radiation dose for astronauts in LEO. Recommended by NCRP-132 (2001). taken from reference [a]



Radiation Materials



- Amount of radiation shielding largely dependent on type of material
- HZE particles of a GCR can split the nuclei of atoms in the shield, leading to more radiation
- Hard to estimate required thickness – several computer models like HEZTRN of NASA Langley
- Lower atomic number materials better for shielding
- Other factors include absorption cross-section and reaction rate parameter
- Most common materials researched are regolith, aluminum, polyethylene, methane, hydrogenated carbon nanofibers (H nanofibers), and hydrogen.

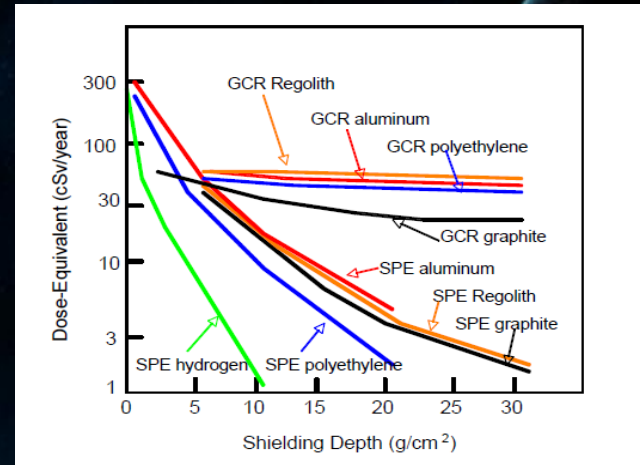


Figure R4: Habitat Dose-Equivalent radiation for several shielding materials for GCR and the August 1972 SPE. The results for the SPE are not annual, but the total for the event, taken from reference [a]

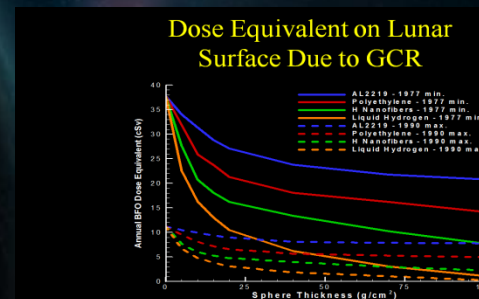
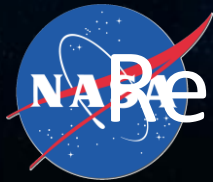
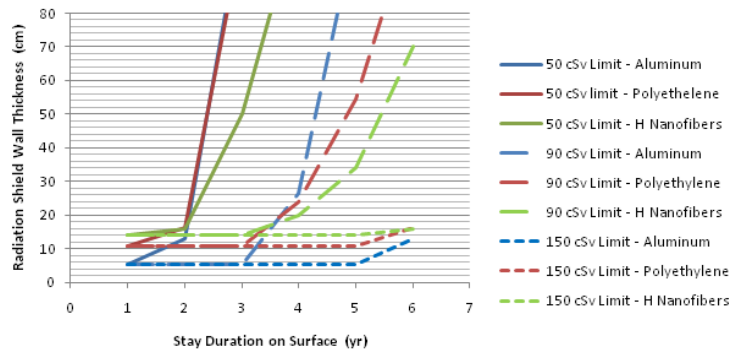


Figure R-4: Habitat Dose Equivalent on Lunar Surface for several radiation shielding materials. Figure taken from reference [d]

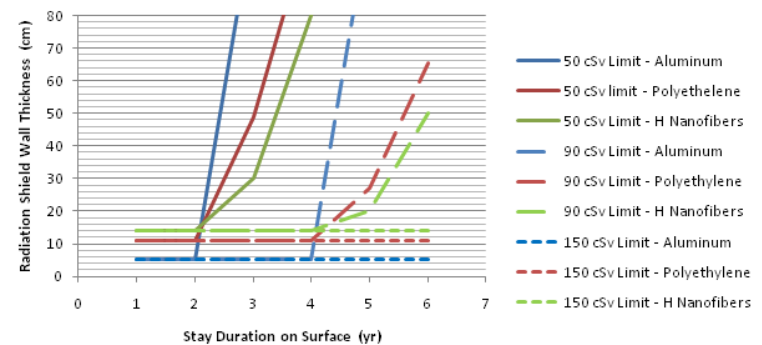


Results: Estimated Linear Thickness of Shield Material

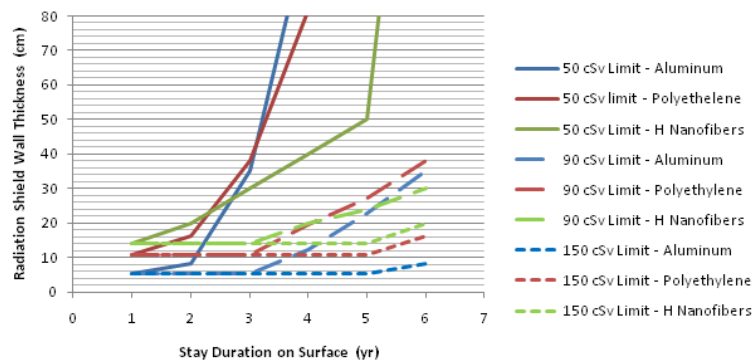
Required Shield Thickness Vs Stay Duration on the Surface of the Moon, Ceres, or Phobos



Required Shield Thickness Vs Stay Duration on the Surface of Mars



Required Shield Thickness Vs Stay Duration on the Surface of Callisto



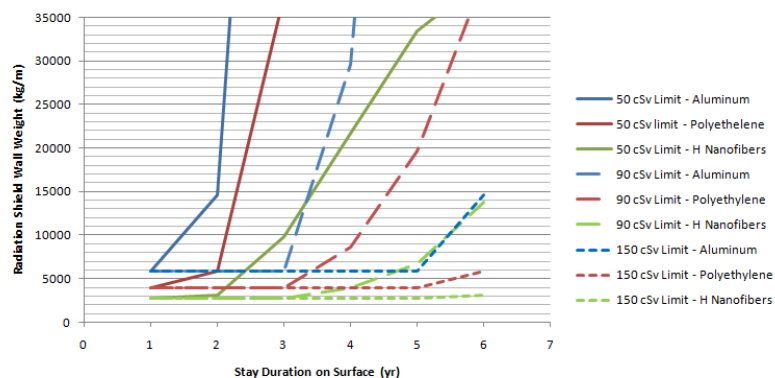
Celestial Body	Linear Radiation Shield Thickness
Titan	Surface Radiation negligible because of the thick atmosphere.
Ganymede	1 m thickness of H nanofibers would allow for a stay of about 2 months.
Europa	Inaccessible with current materials and technology.



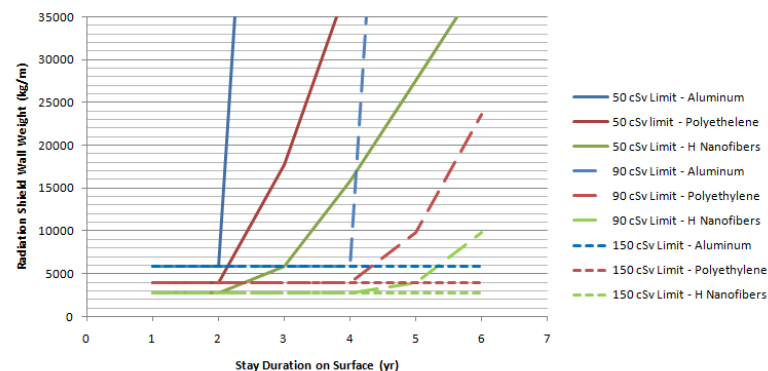
Results: Estimated Shield Mass



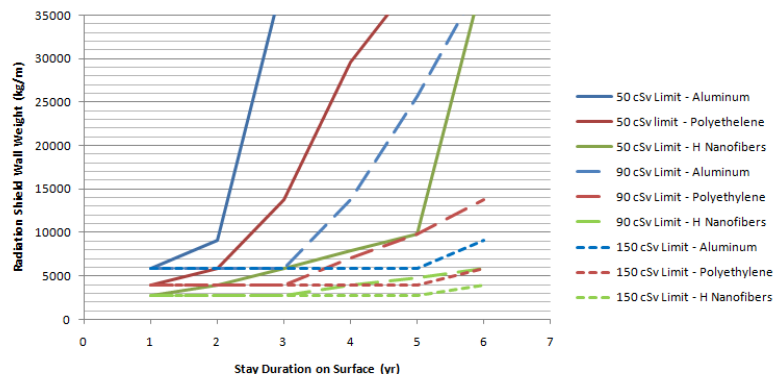
Required Shield Weight Vs Stay Duration on the Surface of the Moon, Ceres, or Phobos



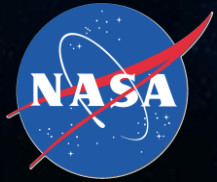
Required Shield Weight Vs Stay Duration on the Surface of Mars



Required Shield Weight Vs Stay Duration on the Surface of Callisto



Celestial Body	Radiation Shield Mass Per Module Length
Titan	Surface Radiation negligible because of the thick atmosphere.
Ganymede	19700 kg/m with 1 m thick H Nanofibers
Europa	Inaccessible with current materials and technology.



Communication



- Optical communication satellite to Earth through NASA SCaN Deep Space Network.
- Conventional transmitter to satellite from colony.
- Wireless communication between modules.
- Computational cluster to handle module and communication data.
- Intranet system.





Travel Times and Food Storage

- Hohmann transfer

$$t_H = \pi \sqrt{(r_1 + r_2)^3 / (8\mu)}$$

- Food Storage

- 1 year for 4 person crew

- 2672 kg
- 7 m³

- Need enough food for rescue mission to arrive

Destination	Years	Months	Days
<i>Callisto</i>	3	9	14
<i>Ceres</i>	1	3	7
<i>Ganymede</i>	3	9	5
<i>Moon</i>	0	0	5
<i>Mars</i>	0	8	10
<i>Phobos</i>	0	9	8
<i>Titan</i>	8	4	13



In-Situ Resource Utilization



Destination	Resources	Products
Callisto	Water ice, CO ₂ ice	Freshwater, H ₂ , O ₂ , methane
Ceres	Liquid water, hydrated minerals, carbonates	Freshwater, H ₂ , O ₂ , methane
Europa	Water ice, liquid water	Freshwater, H ₂ , O ₂
Ganymede	Water ice	Freshwater, H ₂ , O ₂
Mars	Water ice, CO ₂ ice	Freshwater, H ₂ , O ₂ , methane
Moon	Water ice	Freshwater, H ₂ , O ₂
Phobos	Liquid water	Freshwater, H ₂ , O ₂ , methane
Titan	Water ice, nitrogen, methane	Freshwater, H ₂ , O ₂ , carbon-based fuel

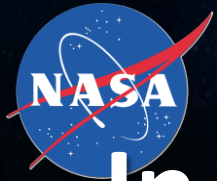


In-Situ Resource Utilization Cont'd

ISRU Process

Resource Extraction

<u>Dusty</u>	<u>Rock</u>	<u>Gas</u>	<u>Icy</u>
<ul style="list-style-type: none">-Scoop/Cut-Scrape Away	<ul style="list-style-type: none">-Drilling-Blasting-Cutting-Impact (jack hammer)-Laser/Solar Concentrator	<ul style="list-style-type: none">-Pump	<ul style="list-style-type: none">-(X) No Blasting-Cutting-Boring-Impact (Jack Hammer)



In-Situ Resource Utilization Cont'd

- Sabatier Reaction



Methane and Water produced from Carbon Dioxide

- Electrolysis



Surface Transportation

- Mobility – Ability to Explore Planet
- Adaptability- To diverse and harsh environments
- Payload Capacity





Decontamination

- Biological

Method

- ultraviolet (UV) radiation

- Chemical

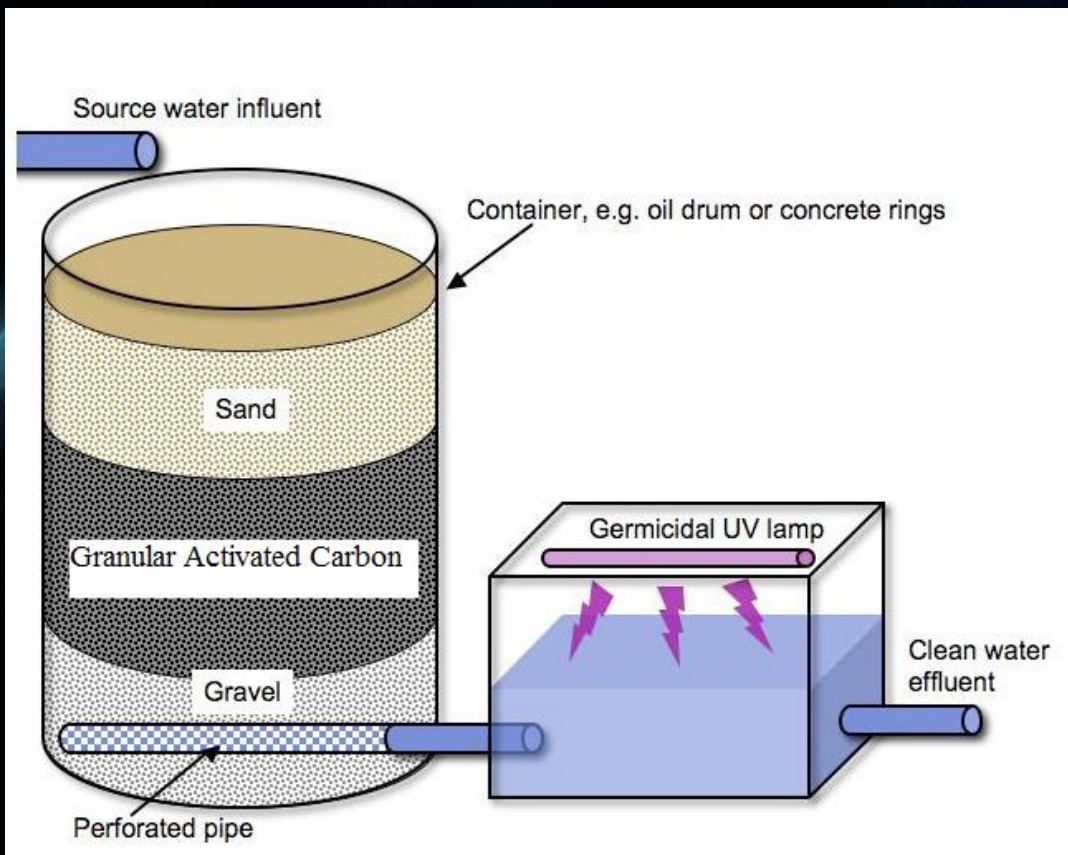
Method

- granular activated carbon (GAC)

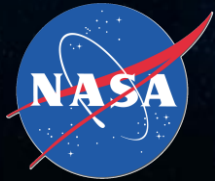
Yearly			
Crew Members	Water Consumed (L)	Urine Produced (L)	Carbon Needed (kg)
1	2	2.5	4.5
3	6	7.5	13.5
6	12	15	27
9	18	22.5	40.5



Data Sheet: Reactor



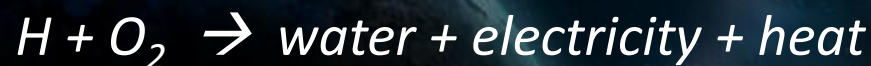
Material of Construction:
Polyethylene
Volume: .05 m³
Height: 1 m
Diameter: 10 in
Sand: 50 cm
Granular Activated Carbon: 27 kg
Gravel: 20 cm



Water Production System

Fuel Cells - Basic Information

- ❑ 3 fuel cells provide drinking H_2O & auxiliary power in the space shuttle; operate as independent electrical power sources, each supplying its own isolated, simultaneously operating 28-volt dc bus
- ❑ Transforms H and O_2 into H_2O , electricity, and heat



- ❑ Requires
 - liquid O_2 tanks
 - liquid N_2 tanks
 - 4 water storage tanks
- [5 kg (165 lb) capacity/ H_2O tank]

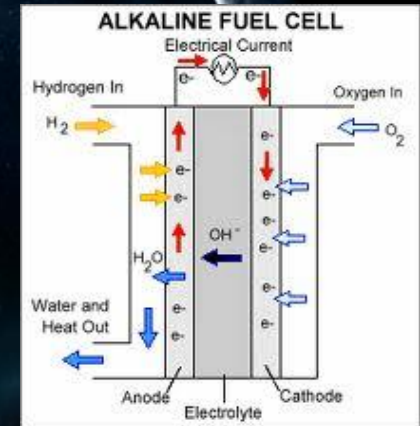


Space Shuttle Alkaline Fuel Cell Power Plant



Water Production System Fuel Cells - Specifications

- ❑ Size: 40" L x 15" W x 14" H
- ❑ Wt = 255 lbs
- ❑ Voltage & Current Requirements/Cell
 - 2 kW at 32.5 V dc, 61.5 amps to
 - 12 kW at 27.5 V dc, 436 amps
- ❑ H_2O produced = 11 kg (25 lb) H_2O /per hr
- ❑ Power provided = 12 kW peak and 7 kW max continuous per cell
- ❑ Notes:
 - ❑ Each fuel cell is serviced between flights and reused until each accumulates 2,000 hrs (83 days) of on-line service.
 - ❑ Need to determine the avg. power consumption of modules





Water Requirements vs. Water Produced Fuel Cells

Daily H₂O Requirements per Crewmember

- ☐ Biological Use = 3.52 kg H₂O/day
 - ☐ Drinking, food, cooking
- ☐ Non-biological use = 3.52 kg H₂O/day
 - ☐ Brushing teeth
 - ☐ Flushing toilet
 - ☐ Showering, washing hands
- ☐ Other uses: cooling, laundry, oxygen production
- ☐ H₂O produced = 11 kg /per hr = 264 kg/day
(may be limited to 83 days of service)

Number of Crewmembers	Water Required (kg/day)
1	7.04
3	21.12
6	42.24
9	63.36

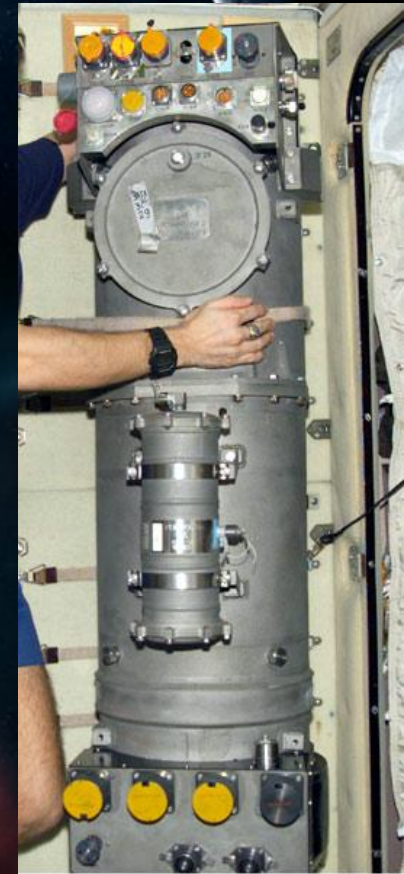


Primary Oxygen Production System

The Elektron-V System



- ❑ Supplies the ISS with an unlimited supply of breathable O_2 , given an unlimited supply of H_2O as raw material
- ❑ Makes O_2 by splitting H_2O into H_2 and O_2 (electrolysis)
- ❑ O_2 is not stored but discharged directly into module's atmosphere at 45 psi
- ❑ H discarded overboard as waste



Russian Elektron O_2 generator



Primary Oxygen Production System

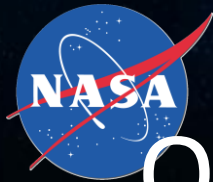
The Elektron-V System

Specifications

- ❑ Produces 1900 L O₂ per day
- ❑ Size: 0.8m x 0.13 (2.62 ft x 0.43 ft)
- ❑ Mass = 150 kg (331 lb)
- ❑ Power load = 860 ~ 1 kW
- ❑ Design life = 3 years



Russian Electron O₂ generator



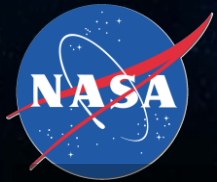
O₂ Requirements vs. O₂ Produced



Daily Requirements per Crewmember

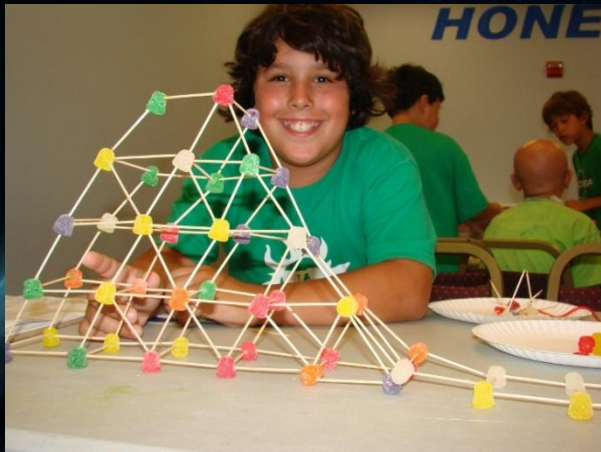
- ❑ 0.84 kg O₂/day ~ 1 kg O₂/day
- ❑ The decomposition of 1 kg of H₂O yields 25 L of O₂ per hr at a pressure of 760 mmHg, which is enough to support one crew member for one day.

Crew Members	Elektron Devices	Water Needed for Elektron (kg and lb)	Power Consumed (kW)	O ₂ Required (L/day)	O ₂ Produced (L/day)
1	1	1 kg (2.2 lb)	1	600	1900
3	1	3 kg (6.6 lb)	1	1800	1900
6	2	6 kg (13.2 lb)	2	3600	3800
9	3	9 kg (19.8 lb)	3	5400	5700



2010 Academy Outreach

We visited two local YMCA Summer Day Camps and presented to 3rd – 4th graders and 5th – 6th graders

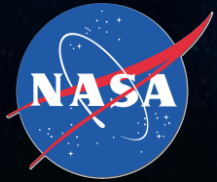




Conclusion



“It is difficult to say what is impossible, for the dream of yesterday is the hope of today and the reality of tomorrow.” ~Robert H. Goddard



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